Title Cognitive Enhancements of Elderly Tai Chi Chuan Practitioners

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by

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MRes.

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Academic Thesis: Declaration Of Authorship

I, JAMES WILLMOTT

declare that this thesis and the work presented in it are my own and has been generated by me as the result of my own original research.

Title of Thesis: Cognitive Enhancements of Elderly Tai Chi Chuan Practitioners

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Abstract

Background

More research is providing support into the capability of tai chi chuan (TCC) to enhance cognitive abilities, neurological functioning, as well as psychosocial wellbeing and quality of life. These areas of the human mind-body complex become at risk during the process of aging, and TCC has the potential to enhance these areas and mitigate cognitive decline for elderly people. The aim of the present study is to investigate whether elderly people who practice TCC possess greater cognitive abilities and quality of life compared to bowls players and a control group.

Method

30 tai chi chuan practitioners, 30 bowls players and 10 control group participants were used in the sample. Only 10 control group participants were used due to complications with recruitment. The Sustained Attention to Response Task (SART) was used to measure sustained attention, the Stroop Test was used to measure executive function, and the Brown-Peterson Task (BPT) was used to measure working memory. The Older People's Quality of Life Questionnaire - Brief was used to measure quality of life. Age, gender, years of experience and self-reported additional activities were recorded. Test order effects were also measured.

Results

Significant differences were found between the tai chi chuan group and bowls group on the Stroop correct responses and the Brown-Peterson Task correct responses in favour of the tai chi chuan group. No other significant differences were found between all groups in cognitive test performance. No significant differences were found between all three groups on quality of life. Significant associations were found between self-reported additional activities practiced and the groups. The total number of activities engaged in and cognitive based activities were found to significantly predict performance on the Brown-Peterson Task.

Conclusion

The data in the present study suggests that elderly people who practice TCC may have enhanced executive function and working memory but not sustained attention compared to bowls players. These findings must be interpreted with caution however due to the methodological complications and mediating factors that confound the reliability and validity of the results. Overall, the study still provides some empirical evidence in support of TCC's potential to enhance cognitive ability in the elderly. More research is required to ascertain the specific components of cognitive ability that are enhanced by TCC.

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Introduction

Tai Chi Chuan (TCC) or Tai Ji Quan (in Chinese pinyin), was created by Chen Wangting in the 17th century in Chenjiagou, Henan province (Guo, Qiu & Liu, 2014). Since then, it has been developed into several forms in China and then shared with the rest of the world, fostering cultural relations with the West. Most martial arts stress more importance on training stamina and strength, TCC distinguishes itself from other martial arts and exercises with its gentleness, slow circular movements and muscular relaxation (Horowitz, 2014). This distinctive uniqueness of TCC may be why empirical research interest has been sparked to discover what neuropsychological and physiological benefits it has to offer. TCC trains physical fitness as an aerobic exercise, and mindfulness techniques are used simultaneously to maintain steady and controlled breathing. The use of cognition is even more complex than this. The forms system of TCC are long series of ordered movements where the placement of the entire body is kept to precision, which requires the practice of memory to learn considerable kinaesthetic information. Considering the complexity of biopsychosocial phenomena that surround TCC, it is an exciting and promising area of research in finding alternative methods of health promotion, since it can train so many different things at once. However, as the components that constitute TCC are multitudinous, this makes measuring the cause and effect nature of the phenomenon in a reductionist way very difficult. Care must be taken to account for the complex interdependent factors at work to attain valid and reliable findings during empirical research (Wayne & Kaptchuck, 2008).

Research into general health benefits have found much in stress reduction and physical health (Jin, 1992). Yang et al. (2015) undertook a large comprehensive review of clinical studies on TCC that found a myriad of physiological and psychological benefits of TCC practice, including; "strength, flexibility, cardiovascular function, balance, pulmonary function, body mass index, biomarker...depression, stress, mood, fear of falling, self-efficacy, anxiety, self-esteem, quality of sleep." However, the findings on TCC's efficacy in treating diseases were uncertain regarding; "osteoarthritis, rheumatic arthritis, breast cancer, Parkinson disease, coronary heart disease, hypertension, and type 2 diabetes." Many of these conditions are associated with ageing, which make TCC research an opportunity to provide elderly people with an effective method of alleviating the symptoms of these conditions, or possibly even preventing these conditions from occurring. As regular exercise is known to combat cognitive decline in the elderly and increase cognitive function, with executive function in particular (Concannon, Grierson & Harrast, 2012), research into the effectiveness of various exercises is important. Physical fitness, motor skills, social interaction and meditation are factors that influence brain structure and subsequently cognition, and the training of this process can be an effective intervention for older people, even those with cognitive impairment (Chang, Nien & Yan, 2014).

Cognitive Ability

In the present study, attention, memory, executive function and their relationship with TCC practice have been examined in the research literature and tested in the experiment. These three aspects of cognitive ability were chosen as they have been found to be prominent cognitive attributes involved in TCC practice and tested in empirical TCC research, which will be discussed. Although the supervisory attentional system and working memory are components of executive function (as well as self-regulation, problem solving, executive control, cognitive flexibility, etc.) (Anderson, Jacobs & Anderson, 2008), these two will be examined separately, whilst executive function will be examined as the overall system of organising information, without being broken down into its components. The purpose of this is to observe the relationship that attention and memory have with TCC in more reductionist detail, whilst gaining holistic information on cognitive ability from measuring overall executive function.

Due to the attention, memory and executive function skills required in TCC, a lot of empirical research has been stimulated into the potential cognitive benefits of its practice. Lu, Siu, Fu, Hui-Chan and Tsang (2013) tested the mind-body application of TCC in an experiment that measured executive function and attention via an auditory Stroop test and postural control via a balancing task. These were performed in single-task and dual-task formats. The TCC group achieved significantly greater results than a control for both tasks, including both single-task and dual-task settings, demonstrating higher executive function and postural control as an effect of mind-body TCC practice. Hawkes, Manselle and Woollacott (2014) used event-related potential (ERP) to measure the executive function of tai chi, meditation, and exercise practitioners. The TCC only group and meditation with exercise group had greater P3b ERP amplitudes at an executive function test than the exercise alone and control groups. Not only does this finding support TCC as form of executive function training, but also supports the premise that TCC is indeed a mixture of exercise and meditation. A study by Reid-Arndt, Matsuda and Cox (2012) examined how TCC could benefit women with a history of cancer. After a 10-week course (60 minutes per class and 2 times per week) the participants gained significant improvements in various neuropsychological tests including memory, attention and executive function. They also showed improved physical measures and self-reported stress reduction. Fogarty et al. (2016) compared a memory intervention program alone against the same intervention combined with TCC using participants with mild cognitive impairment. They did not find a significantly positive difference in the combined group regarding outcome measures of cognition and physical mobility, but both groups displayed an improvement in cognition, especially memory. Although limitations of the study obscured the clarity of these findings, this suggests however that TCC may not be particularly preferable as a treatment of cognition compared to other cognitive interventions.

The process of ageing involves not only physical deterioration, but of cognitive abilities too, which can consequently present emotional difficulties and problems with self-efficacy as a result. As TCC trains the mind and body in these domains, it is an ideal single activity for older people to build resilience in multiple domains (Hogan, 2005). As such, there is now a growing body of research into how effective TCC is in aiding the cognitive abilities of the elderly. Chang, Nien, Tsai and Etnier (2010) have proposed a model of the mediators between TCC and cognition regarding older people which consists of; physical resources (i.e. sleep quality, fatigue), disease states (i.e. hypertension, cardiovascular disease) and mental resources (i.e. depression, self-efficacy). This is a useful model for conceptualising and locating phenomena that is worth measuring on this subject. Man, Tsang and Hui-Chan (2010) found evidence of enhanced cognitive functioning of older Chinese TCC practitioners compared to an exercise group and a control in: sustained and divided attention, everyday memory function and encoding, recall/organization of verbal information. It is worth noting that many of the studies into TCC and cognitive enhancement are unclear on the specific types of TCC training methods involved. As such, it is difficult to ascertain the homogeneity of the TCC interventions in a number of these research examples, this research issue will be discussed later.

Researchers have also looked at how TCC can treat elderly people who suffer from cognitive impairment. A study by Kasai et al. (2010) looked at the neuropsychological effects of TCC on elderly women with mild cognitive impairment. These elderly women displayed a significant improvement in memory as measured by the Rivermead Behavioural Memory Test, as well as self-reported memory satisfaction. Lam et al. (2011) conducted a randomized-controlled trial to measure the cognitive effects of tai chi or stretching exercise on older Chinese people with a very mild dementia rating or mild cognitive impairment. After 1 year, 3 times a week of training, both exercises showed improvements in global cognitive functioning, delayed recall and subjective cognitive complaints and the TCC group showed greater visual spans, with better average scores and stability on the clinical dementia rating than the control group. A study by Li, Harmer, Liu and Chou (2014) investigated cognitive and physical effects of a 14-week TCC programme on older adults with cognitive impairment using a pretest-posttest design. The TCC group showed a significant increase in global cognitive function, which was related to increased balance. Not all studies yield positive results for TCC improving cognitive ability however. Hall, Miszko and Wolf (2009) investigated dual-task ability of postural control and cognitive ability using an obstacle course and the Sensory Organization Test respectively with older people. Those who completed a 12-week tai chi course did not perform significantly better than a control. Chang et al. (2011) conducted a pilot study whereby elderly people with cognitive impairment undertook a 15 week TCC course twice a week for 20-40 minutes per session. They found a marked increase in performance post-test on global cognitive function and processing speed but not on attention and memory. The latter is inconsistent with the majority of cognitive research on TCC as most studies find some form of attention and memory to be improved as a result of TCC practice. However the authors do acknowledge that it was a small sized sample and some of the cognitively impaired participants failed to attend the sessions which may have reduced the reliability of these findings. In a review of research into community-dwelling older people participating in TCC, Miller and Taylor-Piliae (2014) found 10 out of 12 studies reviewed had a significantly positive improvement in executive function, memory, language and learning.

Meta-analyses on this subject have shown the most prevalent cognitive areas that are affected by TCC, as well as problems with the current research; one meta-analysis by Wu, Wang, Burgess and Wu (2013) has found empirical research on the cognitive benefits of TCC to consistently gain positive results in certain domains. Global cognitive function and executive function have been found to be enhanced with a particular improvement of memory function and verbal working memory. In another study, Wayne et al. (2014) calculated a large effect size of executive function results between healthy TCC participants and non-intervention controls and a moderate effect size between TCC and exercise controls. The studies that involved participants with mild cognitive impairment also had greater global cognitive function scores compared to controls reaching statistical significance. Zheng et al. (2015) systematically reviewed four randomised controlled trials and five non-randomized controlled trials and found consistently positive results in the case of TCC's efficacy in enhancing cognitive ability regarding; global cognitive ability, attention, learning and memory, emotion and perception, and executive function. A meta-analysis by Kelly et al. (2014) systematically reviewed the empirical research on the relationship between exercise and cognitive function. They conclude that a combination of aerobic exercise and resistance training is beneficial to executive function, and tai chi specifically is evidenced to be related to efficacious attention and processing speed. However, the authors emphasise that due to inconsistent results across randomised controlled trials, various methods of study design regarding exercise type and intensity, neuropsychological measures, and participant individual differences, the findings of this area of research are quite unreliable.

Neurological Functioning

In order to understand how TCC induces cognitive enhancements it is imperative to learn the neurological changes that are caused by practice. Unfortunately, there is a dearth of research on the neurological changes induced by TCC practice. As TCC involves both aerobic exercise and mindfulness, research on both aspects will be included and integrated in order to compensate. Wei, Dong, Yang, Luo and Zuo (2014) used functional magnetic resonance imaging (fMRI) to investigate neurological differences of TCC experts and novices. They found that the experts had significantly greater homogeneous functioning in the right postcentral gyrus (PosCG), suggesting a focus of function for the sensorimotor processing of touch, and significantly less homogeneous functioning in the left anterior cingulate cortex

(ACC) and the right dorsal lateral prefrontal cortex (DLPFC), suggesting an ability to heterogeneously perform multiple cognitive functions such as attention and executive function. They also found that these differences were related to a better performance on attention network behaviour tests, suggesting that TCC experience can alter the neuroanatomical structure of these areas thus enhancing cognitive capability. Wei et al. (2013) compared MRI brain scans of TCC practitioners and found greater cortical thickness in various gyri and sulci associated with cognitive, sensory and motor functioning. They report that these anatomical changes were consistent with other similar studies on aerobic exercise and mindfulness meditation.

This consistency between TCC and mindfulness meditation is not surprising as TCC involves a meditative aspect, thus it is necessary to investigate empirical data on mindfulness meditation and neuroplasticity. Meditation has been classified broadly into two categories; focused attention meditation and open monitoring meditation (Tsai & Chou, 2016). The former involves maintaining attention on an object along with steady breathing, whilst the latter involves non-judgemental monitoring of experience to make observations on cognitive and emotional patterns. Various styles and sub-types of meditation do exist but this way of classifying meditation is used broadly in the research literature and will be used now to identify the meditation used in TCC. Incidentally, TCC can be classed as focused attention meditation because it requires concentration on breath and body movements rather than the mindful monitoring of cognitive and emotional experience. Fox et al. (2014) conducted a meta-analysis of brain morphometry studies which has shown a moderate effect size of a pattern of neurological differences present in mindfulness meditators. Greater quantities of grey matter were present in the; insular cortex, somatomotor cortices, anterior preceneus (BA 7), rostrolateral prefrontal cortex (BA 10), anterior cingulate cortex and mid-cingulate cortex, orbitofrontal cortex (BA 11/13/47), fusiform and inferior temporal gyri (BA 20/21), and hippocampus. Enhanced white matter pathways were present in the corpus callosum and superior longitudinal fasciculus. Overall, the areas with altered structure are associated with meta-awareness, exteroceptive and interoceptive body awareness, memory consolidation and reconsolidation, self and emotion regulation, and intra- and interhemispheric communication. Larouche, Hudon and Goulet (2015) posit that mindfulness-based interventions have the potential to prevent the transition from mild cognitive impairment to Alzheimer's disease by preventing neurological damage such as inflammation, white matter hyperintensity, and irregular levels of insulin and oxygen caused by stress and depression. Research suggests that cognitive improvements induced by physical fitness may be related to the integrity of nerve cells and neurotransmitters, as well as healthy brain circulation (Espada-Mateos & Calero-Cano, 2016). However, Fletcher et al. (2016) found that some of the areas of the brain that suffered from neurodegeneration were not associated with areas that benefited from physical exercise. This could mean that physical exercise alone is not effective enough to prevent neurological atrophy from aging, which makes research into mindfulness meditation and TCC important to consider. A possible method of staving off cognitive decline from ageing is by combining TCC with other interventions. Yin et al. (2015) detected an enhanced amplitude of low frequency fluctuations in the middle frontal and superior frontal gyri as well as the anterior cerebellum lobe, relating to improved memory in older adults who participated in a six-week intervention that involved cognitive training and group counselling, as well as TCC.

Parkin and Walter (1991) note that the neuro-degeneration that occurs in ageing is associated with cortical atrophy, with regional emphasis in the frontal cortex. Cognitive decline from ageing has also been associated with the compensatory activation of prefrontal areas and executive network, with a reduction in hemispheric lateralization in the prefrontal cortex (Motoaki, 2016). As physical exercise, mindfulness training and TCC can improve executive function and sensorimotor systems, this can aid these compensatory mechanisms and therefore combat cognitive decline from ageing.

Psychosocial Wellbeing

Tai chi is often taught in groups and this allows people who appreciate the art and want to be healthy to socialise by participating together. As such, tai chi can help to maintain psychosocial health as well. Social Cognitive Theory is useful at conceptualising the psychosocial processes of TCC practice; the training process encourages the increase of self-efficacy through attainment of learning the forms and improvements in physiological, cognitive and social states (Taylor-Piliae, Haskell, Waters & Froelicher, 2006). Qi gong is a meditative exercise similar to TCC, that involves focused attention on hand movements accompanied by steady breathing, and shares postures from Chinese martial arts (Ponzio et al., 2015). Unlike TCC, it does not involve the learning of martial forms, but TCC can be said to incorporate qi gong regarding its more meditative aspects. Chan, Lee, Lee, Sit and Chair (2013) performed an experiment to test whether tai chi qi gong could benefit the psychosocial health of chronic pulmonary obstructive disease patients. Interestingly, after the three-month intervention, the tai chi qi gong group did not display significantly improved measures of social support but did after the six-month follow-up where they continued to practice together informally. This suggests that a certain length of time may be required for beneficial psychosocial effects to occur possibly for people to 'break the ice' and make friendships for the TCC practice to become a social event as well as for wellbeing. Not only can TCC affect psychosocial wellbeing, social functioning can affect tai chi performance. Those with a larger social support network can obtain greater benefits in balance from TCC (Siu, Rajaram & Padilla, 2015). A study by Taylor-Piliae, Haskell, Waters and Froelicher (2006) measured psychosocial effects of a 12-week TCC course with Chinese people at risk of cardiovascular disease. They achieved significantly positive results in all psychosocial measures which included: mood state, reduction in perceived stress, self-efficacy in overcoming barriers to TCC and performance, and social support.

Again TCC presents an excellent opportunity to be applied to elderly people. Those who are retired or are living in nursing homes can find a new way to socially interact as well as improving the health of their mind and body. TCC has been successfully used to improve the psychosocial wellbeing of elderly care home dwellers with a significant increase in quality of life and self-esteem from pre-test to post-test (Lee, 2006). Waite-Jones, Hale and Lee (2013) conducted a qualitative study on the perceived psychosocial benefits of tai chi in people with rheumatoid arthritis. Thematic analysis revealed that the participants felt the social aspect of tai chi practice in a group was important to them. They reported that it gave them a feeling of inclusivity in both performing the exercise and sharing their experiences of their medical condition. This study highlights a psychosocial function of tai chi for those who are coping with a medical problem and can use this exercise to psychologically cope via social interaction. A study by Lee, Lee and Woo (2010) have found nursing home residents to have greater self-esteem, physical and mental health related quality of life but not subjective social support after a 26-week TCC course. Although TCC has the potential to facilitate psychosocial health of elderly people entering nursing homes, additional intervention may be required to aid social integration and support. Rawtaer et al. (2015) tested the efficacy of various psychosocial interventions to treat symptoms of depression and anxiety in elderly people, these interventions included: TCC, art therapy, mindfulness awareness and music reminiscence therapy. Single-used interventions were less successful than when multiple interventions were used. This could mean that although TCC and mindfulness are capable interventions in treating psychosocial health, it should not be assumed that they are 'wonder cures' that can resolve all biopsychosocial problems on their own. However, a systematic review by Wang et al. (2009) posits that it is too soon to form any conclusions on the efficacy of tai chi to improve psychosocial wellbeing. The studies they reviewed all yielded positive results, finding depression, anxiety and mood to be the most significant psychosocial qualities that were improved as a result of TCC practice, but some did not achieve significance and many were methodologically flawed.

Goal Setting and Quality of Life

It is also important to consider the motivation behind this practice using goal setting theories. The Theory of Planned Behaviour is adept at predicting physical exercise behaviour with a paradigm that takes social cognitive processes into account; attitudes, social norms and perceived behavioural control (Presseau, Sniehotta, Francis & Gebhardt, 2010). These factors can explain why people practice tai chi and how motivation and discipline can be facilitated. Applying the Theory of Planned Behaviour model to older people has yielded interesting findings, intentions to exercise tend to be lower, yet more likely to be applied into action (Motalebi, Iranagh, Abdollahi & Wai, 2014). Self-perception of fitness and necessary physical activity will affect one's goal-directed attitudes to maintain health and quality of life (QoL). Older people who engage in sports and exercises tend to perceive their level of fitness positively (Espada-Mateos & Calero-Cano, 2016). Therefore physical exercise is vital to facilitating health related quality of life (HRQoL) in the elderly. There are difficulties in defining QoL and HRQoL, an ambiguous subject under much debate with definitions encompassing various aspects of human life such as; mental and physical health, occupation, social relationships (Ogden, 2012). Defining QoL and HRQoL in the context of elderly people may become even more confusing as the QoL problems that elderly people face are largely due to health problems considering the process of ageing directly involves mental and physical decline. For the purposes of this study, QoL will be observed holistically as broad definition of both health and non-health related aspects of elderly living to gain a general observation of QoL. HRQoL is only mentioned in this section involving the consideration of empirical research that focuses on the mental and physical health aspects of QoL regarding TCC and older people.

Biological health is no longer examined without reference to psychological and social factors. As such TCC is an excellent practice to facilitate health in accordance to the biopsychosocial model as it is an exercise where the mind and body are trained equally, and it is practiced socially (Baxter & Francis, 2013). A common goal for elderly people in beginning the practice of various forms of physical exercise is to maintain good health and QoL in order to counteract the negative effects associated with ageing (Concannon, Grierson & Harrast, 2012). These can be loss of mobility and balance, a lowered immune system and proneness to diseases, or neurological degradation and the onset of Alzheimer's and dementia. TCC can also improve sleep quality and subsequently negative psychological symptoms induced by poor sleep in the elderly, demonstrating itself to be an alternative treatment to drugs (Jimenez, Melendez & Albers, (2012). The fear of falling can have a significant impact on the QoL of elderly people as the loss of mobility and balance is a likely process of ageing. Huang, Yang and Liu (2011) conducted a study that compared the positive effects of a cognitive-behavioural intervention with a tai chi intervention compared to the same without the tai chi intervention and a control. They found that including tai chi along with the cognitive-behavioural intervention yielded significant benefits. This included lower fear of falling, higher mobility, social support satisfaction and QoL. The regular practice of physical exercise is integral to longevity of humans, and can prevent the loss of mobility and independence (Roberson, Sigmund, Wang & Valkova, 2015). In the modern age, a sedentary lifestyle is becoming more common and the elderly are particularly at risk of developing this lifestyle after retirement.

Research has consistently supported tai chi as an effective practice to improve QoL and HRQoL; Baxter and Francis (2013) have found tai chi practitioners to possess higher psychological and physical quality of life scores as compared to gym exercisers and book club participants. Roberson, Sigmund, Wang and Valkova (2015) tested the change in HRQoL of elderly retirement home residents after a short 10 week tai chi course. They found a significant increase in HRQoL, self-care, with a decrease in anxiety and depression. A study by Ho et al. (2007) highlights the social benefits of tai chi as well as HRQoL. A group of elderly Taiwanese tai chi practitioners had a higher HRQoL score compared to a control. In addition, despite a decline in QoL in proportion to higher age, an increase in social functioning was found in the TCC group. Dechamps, Onifade, Decamps and Bourdel-Marchasson (2009) measured the post-test effects of frail elderly institutionalised participants who undertook a 24 week tai chi course. They found that HRQoL and self-efficacy had increased significantly. Self-efficacy is an important factor to consider when examining the quality of life of the elderly as their self-perceived ability to use their bodies is just as important as their actual ability with regards to biopsychosocial wellbeing.

The studies discussed demonstrate how useful tai chi is for improving the QoL for elderly people with their difficulties of ageing, but it is also important to look at how effective it is at enhancing QoL of other medical problems. A large meta-analysis by Tao et al. (2016) examined the research available on the efficacy of various forms of traditional Chinese medicine in improving QoL and physiological problems of cancer patients. Tai chi did not significantly improve QoL across the empirical data but did improve the vital capacity of breast cancer patients. This demonstrates the limitations in efficacy of how tai chi can improve QoL. Despite being an excellent biopsychosocial health treatment, it may only be effective for certain people. Heart failure is another threatening medical problem that becomes more likely through ageing. A study by Sun, Buys and Jayasinghe (2014) has found that a tai chi intervention can reduce BMI and blood pressure, and increase the HRQoL of chronic heart failure patients. Additionally, hypertension is a physiological condition that is more prevalent among older people and the physical problems associated with it are determinant to QoL. A study by Tsai, Chang, Beck, Kuo and Keefe (2013) have found TCC to treat the pain and stiffness caused by osteoarthritic knees in older people with mild cognitive impairment. Although they did not apply neuropsychological measures to assess any cognitive improvement, this study demonstrates that older people with mild cognitive impairment are able to participate in TCC and improve their HRQoL from it. Sun and Buys (2015) improved the systolic and diastolic blood pressure, BMI, glomerular flow rate and HRQoL of older Chinese people suffering from hypertension after a 12 month tai chi course. However, against part of their hypothesis, they did not find a significant improvement in low-density lipoprotein, high-density lipoprotein, triglycerides and glucose. Overall, this study is an excellent example of how tai chi can be applied as a biopsychosocial health intervention, especially for older people.

Bowls

Bowls is a competitive sport that involves rolling balls to a designated target over 30-40 metres, the player that has rolled their balls closest to the target wins. Bronikowska, Bronikowski and Schott (2011) identify bowls as a potentially effective recreational activity to keep elderly people mobile and maintain a good QoL. Bowls is a gentle non- aerobic exercise popular among the elderly that requires balance in order to throw the ball, and cognitive usage such as attention and executive function. A study by Sayers, Tweddle and Morris (2015) investigated the balance control of older bowls players during the throw of the balls. They found that balance problems were related more to bowls experience rather than age. This highlights the potential of bowls to treat the balance problems of the elderly. There is no known empirical research on the cognitive benefits of playing bowls and very little research on bowls at all. This may be the first experiment to measure the cognitive skills of bowls players, as very little research exists on the subject.

Research Aims and Hypotheses

The purpose of this experiment is to build on our previous study which investigated if Shaolin martial arts (tai chi chuan and kung fu) could yield improvements in attention and reaction time for practitioners (Willmott & Ertubey, 2014). In this original experiment, there were two main groups, one was the martial arts group which divided into three sub-groups; kung-fu, tai chi, and both kung-fu and tai chi chuan. This consisted of patrons of a martial arts school which were categorised into these sub-groups depending on whether they trained these two types of martial art exclusively or together. The second main group was the control which consisted of randomly selected university students. The present study aims to improve on this experiment in several ways, primarily by focusing on TCC specifically and using other measurements of cognition.

The Office for National Statistics (2013) reports that the population of older people from age 65 onwards increased by 1 million in 10 years from 2001 (8.3 million) to 2011 (9.3 million). This increased presence of older people in the population consequently increases the pertinence of research in treatments for cognitive and physical decline from ageing. Normal cognitive ageing involves the decline of various facets of cognition including; crystallized and fluid intelligence, processing speed, attention, memory, language, visuospatial abilities, and executive function (Harada, Natelson-Love & Tribel,2013). These components of cognition are exactly those which are hypothesised to be enhanced by TCC practice. The empirical evidence reviewed suggests promise in TCC's efficacy to improve cognitive ability. It may also improve psychosocial wellbeing and QoL, however as these two are influenced by many life factors, it is likely that the extent that TCC can improve them is limited by each individuals' biopsychosocial circumstances.

The primary aim of the study is to provide empirical data on the cognitive differences between elderly TCC practitioners, bowls players and those who do not regularly exercise in the areas of sustained attention, executive function, and working memory. Sustained attention will be measured with the Sustained Attention to Response Task (SART), executive function will be measured with the Stroop Test, and working memory will be measured with the Brown-Peterson Task (BPT). These tests were chosen not just because they are valid measures of their respective cognitive trait, but also to take practicality into consideration.

All three are short, relatively easy to understand, and simple to follow on a computer. These are important concerns when administering multiple cognitive tests together to older people, especially if some may not be familiar with computers. The secondary aim is to see the differences between groups on a psychometric QoL questionnaire. QoL will be measured with the Older People's Quality of Life Questionnaire (OPQOLQ). TCC may have the potential to simultaneously improve the cognitive, neurological, psychosocial wellbeing and QoL of elderly people. The importance of finding effective treatments for the healthcare of the elderly cannot be understated.

The overarching hypothesis is that the TCC group will display the highest success rate on each of the cognitive tests and the QoL questionnaire, with the control group having the least success and the bowls group in between. Here it is broken down into sub-hypotheses.

Hypotheses:

1. On the SART, the TCC group will have the fastest RTs (lowest mean RT), most consistent RTs (lowest standard deviation of RT), the highest average of correct responses, and lowest average of incorrect responses of all types (omission errors, commission errors, and total errors). According to these measures of success, the bowls group will come second and the control group last.

2. On the Stroop Test, the TCC group will have the fastest RTs (lowest mean RT), most consistent RTs (lowest standard deviation of RT), and the highest average of correct responses. According to these measures of success, the bowls group will come second and the control group last.

3. On the BPT, the TCC group will have the highest average of correct responses, with the bowls group coming second and the control group last.

4. On the OPQOLQ, the TCC group will have the highest average score of QoL, with the bowls group coming second and the control group last.

Method

Design

A quasi-experimental design was used for practicality, as an experimental pre-post test design would have presented too many difficulties with the time and resources available. For the preliminary analyses, correlations were performed to measure the relationships between age, years of experience, and all test scores. A two-way ANOVA was used to compare age differences between groups. Two t-tests were used to compare gender difference on test performance, and years of experience between the TCC and bowls groups in their respective exercises. A one-way ANOVA was used to observe differences in test order to account for order effects. In the main analysis, a MANOVA calculated the main results, observing differences between all groups on all of the test scores (cognitive ability and QoL). For further analyses, self-reported additional activities were categorised and analysed with chi-squares to look for group associations. Regressions were then performed to observe if additional activities could predict performance on any outcome variables of interest.

Participants

The participants were divided into 3 groups. The TCC group, bowls group, and control group. An a priori power analysis was performed using gpower to calculate the necessary minimum sample size. The following sample sizes were calculated by estimations of effect size:

small effect size 0.1 - 102 total sample (34 in each group), medium effect size 0.25 - 21 total sample (7 in each group), large effect size 0.04 - 12 total sample (4 in each group).

30 participants were planned to be obtained for each group totalling 90 participants. This would surpass the minimum required if a medium or large effect size was observed. Although it is a little short from a small effect size, obtaining a larger sample when considering the practicalities of the data collection, experimental design and time constraints would have been problematic. Such problems with sample acquisition surfaced as only 10 participants for the control group were obtained giving a total of 70 participants. Acquiring an equal gender ratio was not possible and the gender ratio is as follows: TCC group - 5 males and 25 females, bowls group - 20 males and 10 females, control group - 3 males and 7 females. Despite this unequal sample size, the control group will still be included in the analyses as the a priori power analysis revealed that only 4-7 participants are required for 1 group if a large or medium effect size is obtained.

TCC group age statistics: Range - 63 to 88 (25), mean - 73.90, standard deviation - 6.53.
Bowls group age statistics: Range - 62 to 84 (22), mean - 72.77, standard deviation - 5.18.
Control group age statistics: Range - 67 to 88 (21), mean - 76.50, standard deviation - 7.55.

The TCC group sample consisted of students from multiple classes that were all taught by one instructor. They are all taught the same form of TCC, chen style with qi gong and silk reeling exercises, which is tailored to suit older people. Each class is 75 minutes long with a 5 minute break, and held once a week. The bowls group participants came from two different clubs that are in neighbouring towns. The participants here play leisurely and thus details of their frequency and intensity of practice could not be obtained. The control group was gathered from any contacts made, as well as approached at local community areas such as village halls.

Sample Inclusion and Exclusion Criteria:

The minimum age for all participants is 60 years. The TCC group and bowls group are required to have at least 1 year of experience in their respective practice. This is to allow them time to gain the relevant cognitive benefits of their sport. Several of the studies previously mentioned are able to elicit cognitive change in pre-post test experiments in a matter of months, therefore one year should be more than enough to ensure the participants have enough experience. Additionally, research suggests that it may be the continuity of physical exercise practice more so than experience that staves off cognitive decline (Hötting & Röder, 2013). Regardless, a statistical analysis will be conducted to measure the extent that experience correlates with performance to observe whether this becomes a confounding variable. For the control group, participants must not practice any sport or martial art but must be able-bodied. If the control consisted of elderly people from for example a care home who were disabled or physically inactive, this would create a sample bias and an unfair comparison. Bowls was selected because this sport is commonly played by elderly people due to it being physically non-intensive with more prominence on skill. Elderly people that play it should be more physically and mentally comparable to elderly tai chi practitioners thus providing more fair and valid results. Additionally, those with any physical or psychological disability that would affect their ability to perform the tests were not included in the study. The minimum age of all participants will be 60 years, firstly as this is classed as older adult status. Secondly, general cognitive ability has been found to be stable throughout the lifespan until the age of 60, where neurodegeneration begins to cause cognitive decline (Ronnlund, Sundstrom & Nilsson, 2015).

Materials

Sustained Attention to Response Task (SART) - a measure of sustained attention

This test measures sustained attention by recording the reaction times (RT) of participants' response to numbers that flash up on a computer screen. The numbers from 1-9 appear for a short time randomly in succession and disappear again, the participant must click the mouse before they disappear. When the number 3 appears, the participant must not click the mouse. This is a 'go or no-go' system that prevents rhythmic and unconscious pressing of every number and forces the participant to think before they respond to measure attention accurately. The mean and standard deviations of RTs are calculated to measure speed and consistency respectively. The numbers of correct responses and incorrect responses measure success of response. The incorrect responses are divided into omission and commission errors. An omission error is the failure to respond on the 'go' stimuli, and a commission error is the failure to inhibit response on the 'no-go' stimuli. Despite some debate over whether it induces mindless responses to the stimuli, the SART is empirically supported as a valid measure of sustained attention (Dillard et al., 2014).

Stroop Test - a measure of executive function

Participants are presented with words of colours. Half of these words will be in the same colour as the word i.e. Red, Blue, Green (congruent coloured words). The other half will be in a different colour to the meaning of the word i.e. Red, Blue, Green (incongruent coloured words). They must press the corresponding button for what colour the word is written in. The speed at which the responses are given is recorded with means and standard deviations calculated as well as the number of correct responses. As the participants will be elderly, only three colour words will be used (red, blue, green) to make the test more simple to perform regarding cognitive ability and the pressing of keys in response. 30 congruent coloured words and 30 incongruent coloured words will be shown giving a total of 60 words, each form of word is used equally. Executive function is measured by the ability to overcome the Stroop Interference Effect, the problem of distinguishing between varying types of information, where selective attention is also required (Zhang, Ding, Li, Zhang & Chen, 2012).

Brown-Peterson Task (BPT) - a measure of working memory

Participants are presented with a three digit trigram of random consonants eg. FPW, of which they must remember. They are then given a distracter task whereby they must count backwards in threes from a provided number. This is repeated with an increasing 3 second duration each time starting with 3 seconds and ending with 18 seconds to test the deterioration of short-term memory over time. After the distracter task, they must recall the trigram. Please see 'Example Sheet for Instructions' in Appendix 1 for an example of the instructions that appear on screen. There is a total of 6 trigrams in the task and participants are scored on the number of correctly recalled trigrams as a measure of working memory (Mertens, Gagnon, Coulombe & Messier, 2006).

Older People's Quality of Life Questionnaire - Brief Version (OPQOL-Brief)

This QoL questionnaire tailored for older people contains 13 items and is divided into 6 subscales: social relationships; independence, control over life and freedom; home and neighbourhood; psychological and emotional well-being; financial circumstances; leisure and social activities. An example item is 'I am healthy enough to get out and about.' (Please see Appendix 1 for full questionnaire). A statement is given at which the participant must respond by circling the most appropriate answer on a 5-point Likert-Scale ranging from; 1 = strongly disagree, to 5 = strongly agree. Bowling, Hankins, Windle, Bilotta and Grant (2013) calculated a Cronbach's α of 0.856 in a study that measured its internal validity and reliability.

Procedure

Written permission was obtained from the instructor of the TCC classes and chairmen of the bowls clubs who acted as gatekeepers to perform the experiment on their premises. They assisted in recruiting participants from their respective clubs. The written permission was then provided to the psychology school of the university to gain ethical approval before experimentation began. The experiment was only administered before the participants began their TCC class/bowls game. This was to prevent fatigue confounding their performance and by keeping this condition the same, it maintained the reliability of the results. The experiment was explained to each participant, after which they read the experiment brief and filled in the personal details questions (age, gender, TCC or bowls practice, and years of experience in practice of respective exercise). Another question was given: 'What other recreational activities do you practice?' The purpose of this question is to account for other extraneous variables that could confound the results of the experiment. If the participants practice other activities (both physical and cognitive) that could influence cognitive ability, this information can be used to factor in any mediating variables in the analyses. The QoL questionnaire followed after which completed the writing section of the procedure. They then proceeded to complete the 3 tests on a laptop which were run on SuperLab 4.5. Instructions were shown on SuperLab before each test, and an example sheet was used to illustrate the stimuli for the to assist with instruction. This is shown in Appendix 1 under Example Sheet for Instructions, examples for the Stroop Test and BPT only were given as the SART was easier to understand without visual assistance. Finally, participants were given an experiment debrief form to inform them of the details of the experiment and any additional information.

The control group sample was obtained via opportunity sampling, using any contacts made and already known (who fit the inclusion and exclusion criteria) throughout the collection of data. The problems that ensued when obtaining the control group may have mostly been due to the style of recruitment. The TCC and bowls groups were easier to recruit as the TCC instructor and chairmen of the bowls clubs were able to assist in engaging with the patrons of their respective activities. However the control group was recruited opportunistically as it was specified in the exclusion criteria that they could not be part of any sport. As such, there was no assistance in recruiting them and people who were approached had little incentive to participate. Many of the people for the control group were approached at village halls where community activities involving elderly people took place and it was found that these people were quite reluctant to participate. Upon hearing of the cognitive tests they voiced concerns that failing these tests could be a sign that they are losing their mental acuity from old age. It would have been unethical to attempt to persuade people to take part if they could have suffered from anxiety over their performance and this concern became frequent among potential control group candidates. It is for these reasons that recruiting this sample became problematic and only 10 people were willing to participate who did not have any apprehension over the experiment.

Results

Please note that reaction time (RT) is recorded in milliseconds. A lower mean RT is a better result as it indicates a faster RT, and a lower standard deviation of RT is better as it indicates greater consistency of RT.

Please note that there is some missing data for the SART results. Some participants were too slow to respond within the 300 millisecond timeframe thus a mean or standard deviation of RT could not be calculated. All SART results were deleted for these participants as their results are compromised. This occurred for 1 participant in the TCC group, 1 participant in the bowls group, and 2 participants in the control group.

Preliminary Analyses

Table 1

Correlations Between Age and Dependent Variables

Variable	1	2	3	4	5	6	7	8	9	10	11
1. Age											
2. SART Mean RT	.018										
3. SART StDev RT	.078	-.673**									
4. SART Correct R	-.437**	.014	-.150								
5. SART Omission E	.424**	-.010	.140	-.998**							
6. SART Comission E	-.265*	-.019	-.045	.843**	-.877**						
7. SART Total E	.437**	-.014	.150	-1.00**	.998**	-.843*					
8. Stroop Mean RT	.398**	-.087	.267*	-.289*	.283*	-.193	.289*				
9. Stroop StDev RT	.312**	.024	.190	-.252*	.250*	-.201	.252*	.739**			
10. Stroop Correct R	-.258*	-.024	-.114	.139	-.131	.052	-.139	-.137	-.235		
11. BPT Correct R	-.103	.178	-.250*	.080	-.071	-.003	-.080	-.173	-.187	.460**	
12. OPQOLQ	.102	.224	-.341**	.164	-.165	.148	-.164	.058	-.056	.128	.080

Note. * indicates correlation is significant at the level of p<0.05 (2-tailed). ** indicates correlation is significant at the level of p<0.01 (2-tailed).

Another 2-tailed correlation was performed to examine the relationship between years of experience and the dependent variables. This could not be done in the preceding correlation because the control group data needed to be excluded as this non-exercise group has no level experience to be measured. No significant correlations were found between years of experience and performance in all cognitive tests as well as the QoL measure.

A t-test found a significant difference between the TCC and bowls groups in years of experience of their respective exercise $t(40) = -3.85$, $p < 0.001$. The bowls group has the higher average years of experience at 16.08 years whilst the TCC group has the average of 7.54 years.

A two-way ANOVA was conducted to test the overall age difference between groups. No significant differences were observed and thus all three groups are of a similar age which eliminates age as a confounding variable when testing for group differences.

A t-test compared gender difference in performance of all dependent variables. No significant differences were found between males and females in all cognitive ability measures and the QoL measure.

The one-way ANOVA for test order effects found a significant difference in the test orders of the Stroop Mean RT scores ($F(2,69) = 5.65$, $p = 0.005$) and the Stroop Standard Deviation of RT scores ($F(2,69) = 4.96$, $p = 0.01$). No other significant differences were found. When the Stroop Test was performed in between the other two cognitive measures, RTs were both faster and more consistent, and when it was performed last, the RTs were both slower and less consistent.

Main Analysis

Table 2

Descriptive Statistics for Cognitive Measures

Outcome Variable	Group	Mean	Std. Deviation	Minimum	Maximum
SARTMeanRT	TCC	255.381	25.654	155.22	287.25
	Bowls	252.806	37.464	69.00	282.24
	Control	260.274	15.394	230.59	279.00
SARTStDevRT	TCC	38.649	21.830	8.26	86.75
	Bowls	37.955	16.535	14.27	76.37
	Control	42.034	20.770	19.53	81.07
SARTCorrectR	TCC	70.067	34.370	23.00	146.00
	Bowls	79.667	41.600	23.00	155.00
	Control	60.600	34.238	23.00	131.00
SARTOmissionE	TCC	130.200	38.054	45.00	184.00
	Bowls	120.167	46.786	36.00	184.00
	Control	141.100	38.971	64.00	184.00
SARTComissionE	TCC	6.733	4.370	.00	16.00
	Bowls	7.167	5.663	.00	19.00
	Control	5.300	5.736	.00	17.00
SARTTotalE	TCC	136.933	34.370	61.00	184.00
	Bowls	127.333	41.600	52.00	184.00
	Control	146.400	34.238	76.00	184.00
StroopMeanRT	TCC	1243.350	365.117	795.22	2082.95
	Bowls	1214.480	341.357	746.50	2539.32
	Control	1410.183	289.964	1074.73	2091.17
StroopStDevRT	TCC	531.991	405.785	149.74	1744.81
	Bowls	649.791	434.777	202.73	1812.81
	Control	654.165	365.272	241.05	1380.51
StroopCorrectR	TCC	58.433	2.096	52.00	60.00
	Bowls	55.333	5.744	38.00	60.00
	Control	54.300	9.190	30.00	60.00
BPTCorrectR	TCC	3.000	1.174	.00	5.00
	Bowls	1.533	1.137	.00	4.00
	Control	2.700	1.889	.00	5.00
OPQOLQ	TCC	59.40	4.75	50	65
	Bowls	58.07	5.04	50	65
	Control	59.00	5.19	52	65

Using Pillai's Trace, a significant effect of the type of exercise on the DVs (cognitive ability and QoL) was found, $V = 0.47$, $F(18, 112) = 1.92$, $p = 0.021$.

Table 3

MANOVA Between Subjects Effects of all Groups

Outcome Variable	df	F	*p*	Partial η^2	Observed Power
SART Mean RT	2	.106	.899	.003	.066
SART StDev RT	2	.138	.872	.004	.070
SART Correct R	2	.643	.529	.020	.153
SART Omission E	2	.569	.569	.018	.140
SART Comission E	2	.101	.904	.003	.065
SART Total E	2	.643	.529	.020	.153
Stroop Mean RT	2	1.032	.362	.032	.223
Stroop StDev RT	2	.220	.803	.007	.083
Stroop Correct R	2	3.482*	.037	.100	.631
BPT Correct R	2	8.728***	.000	.217	.963
OPQOLQ	2	.495	.612	.015	.128

Note. * indicates significance at the level of $p<0.05$. ** indicates significance at the level of $p<0.01$. *** indicates significance at the level of $p<0.001$.

Levene's Test of Equality of Error Variances revealed that the assumption of equality of variance was violated for three of the DVs: Stroop Mean RT, $F(2, 63) = 4.37$, $p = 0.017$. Stroop Correct Responses, $F(2, 63) = 8.97$, $p < 0.001$. BPT Correct Responses, $F(2, 63) = 6.62$, $p = 0.002$. Due to this violation of homogeneity of variance and the unequal sample size caused by the control group, the non-parametric Dunett T3 post-hoc test is used to examine the pairwise group differences.

The Dunnett T3 test was chosen as the post-hoc test, because a non-parametric conservative test was required due to unequal sample sizes and violations of homogeneity of variance (IBM Knowledge Centre, n.d.). The Dunnett T3 post-hoc test revealed only two significant differences by pairwise comparison. There was a significant difference between the TCC and bowls groups on the Stroop Correct Responses where $p = 0.039$, and again between the TCC and bowls groups on the BPT Correct Responses where $p < 0.001$. In both cases, the TCC group had significantly better scores with the number of Stroop and BPT numbers of correct responses.

Further Analyses

The self-reported additional activities were put into 5 categories according to prominent features that frequently occurred; aerobic exercise, non-aerobic exercise, walking, mental, music. It is debatable how the activities qualified for each category, so for clarification, reasons will be given on how these were divided. Aerobic exercise qualified as anything that involved strenuous physical activity and heavy breathing such as cycling, dance classes, etc. Non-aerobic exercise qualified as physical activity that is less strenuous and does not require heavy breathing such as gardening and more sedentary sports. Although walking could arguably fit into either of these categories, it featured prominently enough to have its own category. Mental activity qualified as any non-exercise based activity that requires cognitive ability such as crossword puzzles or reading. Although music could qualify into the mental category, again it featured prominently and involved either playing an instrument or singing.

During the chi-square analyses, 4 out of 5 of the additional activities yielded at least one cell with the expected count less than 5. As such, Fisher's Exact Test (FET) is reported for these 4 and the Pearson's chi-square is reported for the walking variable (which had no cells with an expected count of less than 5).

There was a significant association between exercise group and aerobic exercise, FET = 12.64, p = .002. There was a significant association between exercise group and non-aerobic exercise, FET = 6.25, p = .04. There was no significant association between exercise group and walking, $x^2(2)$ = .533, p = .851. There was a significant association between exercise group and mental activities, FET = 8.03, p = .012. There was a significant association between exercise group and music, FET = 22.31, p < .001.

To measure how the additional activities predicted the outcome variables that yielded significant results in the MANOVA (Stroop correct responses and BPT correct responses), the additional activities were totalled into three new variables; total activities, physical activities, mental activities. The total activities are simply the total amounts of all activities engaged by each participant. The physical activities are the total amounts of the 3 categories; aerobic exercise, non-aerobic exercise and walking. The cognitive activities are the total amounts of both mental and music activities. The purpose of this more broad categorisation is to make a general observation of whether physical or cognitive activities predict the outcome variables.

Table 4

Single Regression to Predict BPT Correct Responses from Total Activities

Model	B	SE B	β	*p*
Constant	1.8	.31		< .001
Total Activities	.37	.18	.24	= .046

Total activities has been found to significantly predict performance on the BPT to the level of $p < 0.05$.

Table 5

Multiple Regression to Predict BPT Correct Responses from Physical and Cognitive Activities

Model	B	SE B	β	*p*
Constant	1.85	.30		< .001
Physical Activities	.13	.20	.08	= .519
Cognitive Activities	.83	.27	.36	= .003

The physical activities variable does not predict BPT performance, however the cognitive activities variable significantly predicts BPT performance to the level of $p < 0.01$.

The same regressions were performed for the Stroop correct responses and no statistically significant results were obtained. Neither total activities, physical nor cognitive activities predicted performance on the number of Stroop correct responses.

Discussion

The hypothesised order of group test performance was only achieved to precision for 2 variables, Stroop StDev RT and Stroop Correct R. The TCC group performed the best whilst the control group performed the worst, additionally the TCC group had a significant difference compared to the bowls group on the latter variable. This pattern did not follow for all of the other test scores. For the SART results, the bowls group performed the best but the control group did have the lowest average scores. The only variable supporting the null hypothesis for the Stroop Test was on Stroop Mean RT where the bowls group had the fastest RTs but again the control group performed the worst. For the BPT, the TCC group did have a significantly greater performance than the bowls group, however the control group performed better than the bowls group. All three groups were almost identical for the QoL test. Overall, the control group did at least follow the hypothesis of the lowest performer for all SART variables (except for commission errors) and all Stroop Test variables. The TCC group followed the hypothesis in its performance of the Stroop StDev RT, Stroop Correct R and BPT results, the bowls group only followed the hypothesis for the same 2 Stroop measures. However, only 2 significant differences were found with the differences between the TCC group and the bowls group on the Stroop Correct R and BPT Correct R, giving the only reliable probabilities of difference. The null hypothesis was supported for the order of group performance on all other measures which are the majority.

Main Findings

MANOVA

Tables 2 and 3 present the descriptive statistics and group difference respectively for the performance of outcome variables. The findings of the SART yielded negative results as the TCC group performed worse than the bowls group on all measures. The bowls group was not significantly better statistically than the TCC group on all SART measures however. The bowls group had faster RTs, more consistent RTs, more correct responses, less omission errors and more total errors but more commission errors. Care must be taken in interpreting the commission errors. Assuming that the findings are valid, this could indicate that the bowls group were less able to inhibit their responses to the 'no-go' stimuli, and the TCC group were able to inhibit theirs. Removing that assumption, it could mean that the TCC group were simply too slow to respond to the 'no-go' stimuli anyway considering their mean RTs and correct responses were less successful. They could have attempted to respond on the 'no-go' but were too late and thus would have still been given a correct answer by avoiding the commission error. Overall, the SART results indicate that both groups had a similar ability in sustained attention with the bowls group being marginally better and thus do not support the hypothesis. The findings are inconsistent with studies that find greater attention ability: (Lu, Siu, Fu, Hui-Chan & Tsang, 2013; Reid-Arndt, Matsuda & Cox, 2012; Man, Tsang & Hui-Chan, 2010). However, some studies have not found positive results to support the hypothesis that TCC improves these cognitive abilities, consistent with the present study's findings on attention ability: (Hall, Miszko & Wolf, 2009; Chang et al., 2011).

The Stroop Test yielded mixed results. The negative result was that the bowls group displayed a faster mean RT than the TCC but this was not statistically significant. However the TCC group had a non-significantly more consistent RT and a significantly higher score of correct responses. As there are no significant results for both RT measures, no conclusions can be drawn as both groups displayed similar levels of selective attention in their performance. The TCC achieved a significant difference on the Stroop number of correct responses to the level of $p < 0.05$. The TCC group had the higher average score of 58.43 compared to 55.33 of the bowls group. This is close to a perfect score of 60, which many TCC participants did achieve, demonstrating great competence at this measure. The TCC group's significantly positive findings on the number of correct responses demonstrate a greater ability to account for the Stroop Interference Effect and correctly distinguish between word and colour. This result suggests that the TCC group possess an enhanced executive function, supporting the hypothesis. However the reaction time results are inconclusive, perhaps suggesting that some areas of executive function are enhanced, but others are similar to the bowls group such as selective attention and processing speed. Additionally, the greater accuracy achieved may be due to the slower response times whereby the TCC group has given themselves more time to process the information. The findings are somewhat consistent with empirical research that has found TCC practitioners to have greater executive function ability: (Lu, Siu, Fu, Hui-Chan & Tsang, 2013; Hawkes, Manselle & Woollacott, 2014; Reid-Arndt, Matsuda & Cox, 2012).

The TCC group achieved a significantly greater difference on the BPT correct responses to the level of $p < 0.001$, a larger significance level than the Stroop correct responses, showing even greater success on this cognitive test in comparison to the bowls group. The TCC group had an average score of 3 out of 6, whereas the bowls group had an average score of half of this at 1.53 out of 6. The participants frequently admitted that this test was the most difficult, which showed as no participant was able to recall all 6 trigrams. The impressive average score of the TCC group provides a promising result in support of the hypothesis, providing evidence to suggest that the TCC practitioners possess enhanced working memory ability. This significant result is more robust in support of the hypothesis compared to the Stroop Test results, as the success of this test is determined by just one variable. Whereas, the significant difference for Stroop number of correct responses is one-third of that test, and partially supports the hypothesis for the TCC group's performance on that particular cognitive ability. Overall, the BPT scores of the study are consistent with empirical research that supports the efficacy of TCC in enhancing working memory ability: (Reid-Arndt, Matsuda & Cox, 2012; Fogarty et al., 2016; Man, Tsang & Hui-Chan, 2010; Kasai et al., 2010).

There was not a significant difference between all three groups on the scores of the OPQOLQ, which did not support the hypothesis that the TCC group would have the best self-reported ratings of QoL with the control having the lowest. A high measure of QoL was found in all three groups, with the vast majority of answers being 'agree' or 'strongly agree' and few participants choosing the less positive answers. No studies were found that use this questionnaire to compare TCC or any physical exercise intervention with a control.

The partial eta squared and observed power figures provide interesting data. The BPT results are strengthened by these figures as a very large effect size is to be observed, demonstrating a large magnitude of the effect that the different exercise groups had on working memory ability. This test also had a very high observed power with a 96% chance of gaining a significant result, however this variable was the only one with an observed power with the minimum desired level of 80%. Unfortunately this may suggest that a larger sample size may have been needed to acquire significant results for the other tests (assuming there is an effect to be found). The only other significant result, the Stroop correct responses, gained a medium-to-large effect size, again demonstrating a good effect size for the effect that the difference in exercise groups had on executive function.

Preliminary Findings

<u>Correlations</u>

The correlations between age and the dependent variables in Table 1 showed interesting relationships. Regarding the SART, the mean RT and standard deviation of RT was positively correlated with age but did not achieve significance and no reliable conclusions can be drawn here. There is a significant correlation between age and the correctness of the SART scores. The number of incorrect responses depends upon the number of correct responses so if one has a significant correlation, all of them will. Age is negatively correlated with the number of correct responses, the younger the age, the more correct responses. This shows that age was a significant predictor of having the speed to respond within that 300 millisecond timeframe and consequently, age positively correlated with the total number of errors significantly. Age also significantly negatively correlated with the omission errors as expected; the older the age, the more 'go' responses were missed out from slowness. Age was negatively correlated with commission errors significantly. Although errors are a measure of failure and the other errors are correlated with older age, this result is also expected as it shows that the younger the participants were, the quicker they were to respond. It could also mean that the older participants were able to inhibit their responses for this type of stimulus, but it is unclear whether this was due to slowness or not. Regardless, even if the younger participants did not have the cognitive ability to inhibit their responses to the 'no-go' stimuli, their speed still gave them greater success as the 'go' stimuli vastly outnumbers the 'no-go' stimuli. Additionally, it may be that the participants who had fewer commission errors also did not have the cognitive ability to inhibit their response, but they could have been just too slow and responded to the 'no-go' stimuli after the 300 milliseconds. These correlations between age and correctness of responses are consistent with Staub, Doignon-Camus, Bacon and Bonnefond (2014) who posit that the older people develop greater cognitive control after finding older participants to have better sustained attention than younger participants on the go/no-go version of the SART. Interestingly, they found that on the traditionally formatted task version of the SART where the go/no-go roles of the stimuli are reverses, younger participants performed better. Additionally, after testing participants of various ages on the SART, Zavagnin, Borella and De Beni (2014) found that although older participants suffered less from mind wandering, they still performed worse than the younger ages on RT and numbers of errors. However, these studies compared much younger participants whereas all participants in the present study are of a similar age. Overall, the SART correlations show the relationship that sustained attention declines with age.

For the Stroop Test, age was positively correlated with both RT measures and significantly so, with higher age being associated with slower and less consistent RTs. A significant negative correlation is found between age and the number of correct Stroop Test responses, with younger participants having more successful answers. These correlations suggest that executive function declines with age. This is consistent with Amato et al. (2006) who found lower scores on the Stroop Test to be related with higher age.

Interestingly a non-significant p value was found for the negative correlation between age and BPT scores. Considering significant correlations have been found thus far suggesting a decline in sustained attention and executive function with increased age, this pattern was expected to follow regarding working memory. This finding could suggest that although working memory (as measured by the BPT) does decline with age, it may not decline significantly within this age range (or at least, the ability to perform this particular memory task does not decline significantly within this age range).

The only significant correlation for years of experience was with the standard deviation of RT for the Stroop Test. The higher the years of experience, the less consistent the RTs were. This is peculiar as one would expect more experience to be associated with better performance. Considering that the other results did not significantly correlate with years of experience, it is probable that this significant one is a statistical anomaly. The overall non-significance suggests that higher years of experience in their respective activity did not improve their cognitive ability dramatically, and perhaps a short time of experience is enough to elicit cognitive improvements. This is supported by Swagerman et al. (2015) who found a weak association between long-term participation of physical exercise and high cognitive ability. Frequency of practice may also not elicit a significant difference in cognitive ability (Groot et al., 2016). Several studies have been unable to find a significant correlation between the length of time of TCC practice and neurological changes, it may be that intensity of practice is a better correlate (Wei et al., 2013).

Age ANOVA

It was important to ensure that the participants were of a similar age and were within a certain age group, as older adults (65+) have been reported to receive stronger improvements of cognitive processes from physical exercise compared to younger-older adults (50-64) (Kelly et al., 2014). As there was no significant difference in age between groups, the possibility of age difference confounding the results can be ruled out. In addition, there was no significant difference of age between genders which also rules out another threat to statistical reliability. As shown in Table 6 in Appendix 2, the mean ages of each group are similar and in the 70s: TCC - 73.9, bowls - 72.77, control - 76.5. As age is a strong predictor of cognitive ability, it is fortunate that age difference had little probability of confounding the reliability of the results.

Gender

No significant difference was found between males and females on all cognitive measures in the t-test. The TCC group had much less males and much more females than the bowls group. Since there is no significant difference in performance and therefore cognitive ability between genders, this gender imbalance is less problematic regarding the reliability of the results. The empirical evidence on gender differences for these cognitive tests is limited; Chan (2001) did not find gender to make a significant impact on SART performance, while Baroun and Alansari (2006) found females to have faster RTs than males in response to the Stroop Test when naming colours but did not find a difference in the Stroop Interference Effect. No studies were found that compare gender differences on the BPT.

Years of Experience

There is a significant difference between the years of experience of the two groups, the average for TCC is 7.54 years and the average for the bowls group is much greater at 16.08 years. The purpose of this t-test is similar to the age ANOVA, to account for the possibility of this variable confounding the reliability of the results. As the correlations between years of experience and the dependent variable scores did not show any positive relationships, this reduces the likelihood of years of experience confounding the results because years of experience was not associated with superior performance. However, as correlation does not determine causation, it is impossible to determine for certain whether the bowls group had enhanced their cognitive abilities from their extensive experience, it could also be why they performed well on the SART. There is a chance that the TCC group would have performed better if their years of experience equalled the bowls group's, but as the correlations did not show a positive relationship between years of experience and performance, this supposition has little evidence to be dwelled upon considering some studies do not find a significant relationship between long-term physical exercise and cognitive ability (Swagerman et al., 2015).

Test Order Effects

Two dependent variables displayed a significant difference of test order effects both to the level of $p < 0.01$; Stroop mean RT and Stroop standard deviation of RT (Please see Table 8 in Appendix 2 for full table). It is not certain why these are the only two variables that were affected by test order. One possible explanation is that the Stroop Test invokes a complex set of cognitive processes; executive function, global cognitive function, selective attention. Whereas the other two tests focus on particular cognitive processes; sustained attention and working memory for the SART and BPT respectively. Due to the cognitive complexity of the Stroop Test, more significant order effects may have occurred, although this is conjecture. Table 7 in Appendix 2 shows that both variables displayed the same pattern of superiority and inferiority of scores in each order. The fastest average RT and most consistent RT was found in the order of; SART, Stroop, BPT (with the Stroop Test taken in the middle). The slowest average RT and least consistent RT was found in the order of; Stroop, BPT, SART (with the Stroop Test taken first). This gives the moderate average scores in the order of; BPT, SART, Stroop (with the Stroop Test taken last). This is explainable by the common effects of order. When the Stroop Test was taken first, the participants were new to cognitive testing and had no practice, when the Stroop Test was taken last, fatigue may have reduced performance and attention after taking two cognitive tests previously. As such, taking the Stroop Test in the middle would allow positive order effects from practicing the first cognitive test, and be too early to suffer from fatigue and inattention.

Further Findings

Chi Squares of Additional Activities

Walking is the only additional activity that is not significantly associated with a particular group or groups. All other additional activities showed significant group associations which demonstrates the differences in lifestyle and hobbies between the groups. This can be examined in tables 9 - 13 in Appendix 2 which list the cross tabulations that detail the frequencies that each additional activity occurred in all groups by numbers and percentages. As the control group is smaller it is useful to look at the percentages for this group.

The TCC group has the largest frequency of aerobic exercise with over half of the group engaging in other aerobic exercises. The bowls group has a very low frequency of aerobic exercise even compared to the control group's small sample. The TCC group has the lowest frequency of non-aerobic exercise, whilst the bowls and control groups have the same percentage of participants engaging in this type of activity. All three groups have very similar percentages of participants (roughly half of their respective groups) who engage in walking. The bowls group has the lowest frequency of mental activities. Despite being one third of its size, the control group has a higher number of participants that engage in it as well as the highest percentage. The control group has the highest number of participants that engage in music despite its small sample size, with a very large percentage. The bowls group does not have any participants that do music related activities. The TCC group has low frequency of participants that engage in music but still higher than the bowls group.

Overall, the TCC group is the most physically active due to its high participation of aerobic exercise, and it is also more active in the cognitive based activities compared to the bowls group. The bowls group seems to be the least active out of all three, but has a preference for non-aerobic exercise (as is the nature of bowls itself too). The equality of walking frequency between all groups is demonstrative of the importance that this is placed among elderly people. The participation of other non-exercise based activities displayed by the control group may indicate that non-physically active elderly people are likely to find alternate hobbies and interests to maintain an active and interesting lifestyle with a focus on cognitive stimulation.

Regressions

The results of the regressions in Tables 4 and 5 provide very useful data to assist in the interpretation of the BPT findings by accounting for the confounding variables of the lifestyles of the participants. Both total activities and cognitive activities significantly predict performance on the BPT, whereas physical activities did not. This may explain why the hypothesised order of group performance did not materialise where the control group performed better than the bowls group on this test. The control group was the most active in cognitive activities (mental and music), therefore their high performance on the BPT and competent working memory is likely to be attributed to their practice of cognitive activities. This also strengthens the possibility that the TCC group has gained its greater working memory ability from TCC practice, as they still outperformed the control group despite engaging in more physical activities rather than cognitive ones. However, the TCC group does practice more cognitive activities than the bowls group, thus it is possible that the significant difference on the BPT between these groups is owed partially by this rather than TCC practice. Although, as physical activities did not significantly predict performance on the BPT, this reduces aerobic exercise as a confounding variable in its influence of the TCC group's performance. Overall, these regressions have supported the main positive result that the TCC group may possess greater working memory ability. Additionally, they demonstrate the importance of lifestyle choices for elderly people with different interests and their effects on cognitive ability.

The regression results on physical activity is consistent with a study by Swagerman et al. (2015) who found little evidence to support the capability of physical exercise to enhance cognitive ability, where the only cognitive attribute that was strongly improved by physical exercise was attention. However it is inconsistent with a meta-analysis by Groot et al. (2016) which revealed that people suffering from dementia can gain cognitive benefits from physical exercise, but less positive effects can be gained from non-aerobic exercise alone, thus either aerobic alone or a mixture of both is preferable. An example of one of the mental activities was crossword puzzles, and research supports the efficacy of this in improving cognitive ability. Although Hardy et al. (2015) used crossword puzzles as a control to be compared against a cognitive training programme (where the intervention induced significant improvements in various cognitive attributes compared to the control as hypothesised), the results for the crossword group still showed improvements in various cognitive attributes, including a go/no-go task. Empirical evidence is also in support of the efficacy of playing instruments in enhancing cognitive ability; Rodrigues, Loureiro and Caramelli (2013) have found orchestra musicians to have significantly better attention ability in each component of attention; sustained, selective and divided. Additionally, the more years of experience they had studying music, the better their RTs. It can be a useful practice for the elderly, as playing the piano can act as an intervention to combat cognitive decline by improving executive function and working memory (Bugos, Perlstein, McCrae, Brophy & Bedenbaugh, 2007).

Limitations

Due to the study using a quasi-experimental design, the process of TCC causing cognitive effects was not measured experimentally with a pre-post test design. Incidentally, the findings cannot provide evidence to suggest that TCC causes cognitive enhancements, just that elderly people who practice TCC may possess greater executive function and working memory ability, with the likelihood of this being caused by TCC. This design may provide some ecological validity concerning the potential of TCC to enhance cognitive ability in the elderly. All participants began TCC in the latter part of their lives, probably with the purpose of increasing their longevity. Although the study could not measure the direct pre-post test effects of TCC practice, it demonstrates that elderly people may be able to benefit from practice even when beginning it at old age. Those who commit to TCC practice at a young age as their primary hobby or professionally are likely to gain more significant cognitive benefits than those who begin it as a secondary hobby in old age. Hence, this quasi-experimental design may provide ecological validity for the ability of TCC to enhance cognitive ability for anyone who practices it at any time in their life and however serious their commitment. However, this study is unable to determine whether TCC practice just bestows cognitive enhancements, just slows cognitive decline, or accomplishes both.

The SART presented several methodological issues. If the response to the stimuli exceeded 300 milliseconds, 0 milliseconds would be recorded as the RT due to the way Superlab was programmed. This may have produced an unreliable calculation for the overall mean and standard deviation for both groups. Again, as mentioned, the 300 millisecond timeframe may have been too difficult for elderly people to respond to, as mentioned previously a few participants failed to be fast enough to respond to a single stimulus giving causing some missing data. Additionally, it was observed that several participants struggled to use the mouse dextrously, and found difficulty in pressing their finger onto the mouse with speed which is required for the short timeframe that the stimuli are presented. As is common among elderly people, the majority of the participants expressed that they are not regular users of computers. As an age group, they had a similar inexperience, however some participants appeared to be more familiar with using a mouse than others. Consequently, the measurement of sustained attention may have been obscured by the measurement of finger dexterity and computer familiarity. All of these limitations regarding the SART may have produced quite unreliable results. It cannot be assumed that this is the reason for the negative result and contradiction to the hypothesis regarding sustained attention however. The SART may have been an inappropriate test for elderly people, perhaps a different measure of attention more suitable to older participants would have procured more reliable findings. Researchers disagree on what the SART actually measures and how it affects the findings of elderly samples, a study by Carter, Russell and Helton (2013) suggests that the SART is a stronger measure of response inhibition than sustained attention, and disputes the idea that the SART causes mindless responses from participants. If this is true, it could explain why the TCC group did not perform significantly better on the SART, when TCC aims to train attention ability. The inconsistent findings on the sustained attention ability of the elderly are likely due to the incomplete theoretical conceptualisation of attention and the factors that comprise it (Staub, Doignon-Camus, Despres & Bonnefond, 2013). In order to accurately measure attention ability, perhaps multiple attention based neuropsychological tests need to be implemented.

Although the cognitive tests are perfectly valid measures, they do not measure other components of the same cognitive area. Only sustained attention was measured whilst divided and selective attention was not. Executive function was measured broadly without examining its components in detail (except for parts of attention and working memory by the other two tests). Lastly, the BPT focuses on short-term memory and not other components of working memory such as the visuospatial sketchpad. Chan, Wu, Liang and Yan (2015) have demonstrated the relationship between visuospatial working memory and sequential motor skills by improving motor skills via visuospatial working memory training. Therefore, visuospatial memory may have been an ideal area of working memory to investigate in a TCC study considering the visual and spatial processing of sequential movements required to be memorised in its practice. As stated, these tests were chosen partly for the sake of practicality and to gain a broad set of data on various cognitive abilities, thus these limitations are more beneficial to consider for future research that focuses more on particular cognitive abilities.

Another minor limitation of the study is the imbalance of males and females within and between groups. There were far fewer males in the TCC group and fewer females in the bowls group. However, as no significant difference was found between genders in the performance of the cognitive tests, this sampling issue becomes less problematic and has little chance of confounding the reliability of the results. Caution must be used when interpreting gender differences. A study by Jorm, Anstey, Christensen and Rodgers (2004) at first found gender superiority for both males and females on certain cognitive tests, but when various physical and psychological health factors including education and language were accounted for, the better male results were reduced but the better female results were increased further. In addition, Tommasi et al. (2015) did not find significant gender differences in cognitive ability in Italian elderly participants but did find a significant association with intelligence for both genders. Despite gender stereotypes assuming that males have superior skills in mathematics and spatial awareness, while females have better verbal skills, Hyde (2016) has formulated the Gender Similarities Hypothesis, which refutes these stereotypes based on the substantial empirical evidence demonstrating more similarity in cognitive ability between genders rather than difference.

The additional activities recorded in the present study are limited in detail. As this information was obtained via self-report, the participants may have been inadvertently inaccurate when stating all activities they do, as well as the magnitude of the role that these activities play in their lives. The frequency, intensity and experience of these activities was not measured, thus it is unknown whether they played a minor or major role in the participants' lifestyles, and consequently, the degree to which they could influence the results. Secondly, a prominent limitation of this study is the possibility of other extraneous variables. The education of each participant was not accounted for and education is a prominent causal factor on cognitive ability and particular cognitive skills (Ritchie, Bates & Deary, 2015). However, inconsistent evidence has been found with the relationship between education and Stroop Test performance; Amato et al. (2006) found no significant difference was made by education, whereas Moering, Schinka, Mortimer and Graves (2004) found age, gender, and education to have an influence on Stroop Test performance in a sample of elderly African Americans. Chan (2001) did not find education to make a significant impact on SART performance. This may suggest that although education does have a strong influence on intelligence, general cognitive ability and specific cognitive skills, it may not affect performance on all neuropsychological tests, such as those that measure components of certain types of cognitive ability. Hogan (2005) refers to research indicating that lowly educated people benefit from hobbies and physical activity more than highly educated people when taking cognitive tests. Incidentally, it may be possible that education is more predictive of cognitive ability than exercise and other activities. Individual differences in health circumstances may also have affected each participant's performance. Through ageing, each person can suffer from a variety of minor or major health problems down to their genetic predispositions and lifestyle. Although people with serious mental health problems such as dementia were excluded from the study, minor physical ailments such as eye problems, arthritis, etc. that are common in the ageing population were not controlled. It was noted that participant 29 of the TCC group had experienced a stroke several years before the study, this person was healthy enough to participate and even scored higher than average on most measures regardless. When considering the extensive myriad of possible extraneous variables of physical activities and cognitive activities (and the frequency, intensity and experience of such activities), it is unclear how much the results have been influenced. However, it is reasonable to conclude that the BPT results of the TCC group are likely owed to TCC practice. It still gained a higher average score than the control group, despite practicing less cognitive activities which were found to significantly predict BPT scores. Additionally, physical activities did not predict BPT performance and the high frequency of aerobic exercise partaken by the TCC group is reduced as a confounding variable.

The results were somewhat obstructed by the failure of obtaining the full sample of the control group. As aforementioned, many potential candidates expressed anxiety over the hypothetical self-interpretation of their performance, that failure would suggest a sign of oncoming dementia or something to that effect. Additionally, the opportunistic fashion of requesting people to participate gave little incentive and motivation. Whereas, the TCC instructor and bowls chairman assisted in approaching people. As stated, care homes were not used in order to obtain a fair comparison between groups, but in hindsight, it may have been more practical to have found another institution that elderly people frequent to form the control group.

Conclusion

In the previous study which this one is built upon, only the SART was used (Willmott & Ertubey, 2014). The control group had faster RTs than the martial arts group, although this difference was insignificant. The martial arts group did however have significantly more consistent RTs, and the number of incorrect RTs between groups was similar. Higher age and females were associated with more consistent RTs and slower RTs. These results of the original experiment suggest that Shaolin martial arts may improve attention ability in a specific way, (evidenced by the consistency of RTs) but not significantly enough for attention overall as the response speed was slower. The SART results of this previous study are somewhat consistent with the present study; the martial arts (including TCC) and TCC group respectively showed a higher mean RT and a similar number of errors compared to their respective controls. The difference is the previous study's martial arts group displayed more consistency of RT which was statistically significant, contrary to the present study.

The data of the present study suggests that TCC practitioners may have enhanced working memory and components of executive function ability but not sustained attention compared to bowls players. It must be highlighted that this does not necessarily indicate that this result can be generalised to the whole elderly population. The TCC group may have performed significantly better on the BPT compared to the bowls group but not significantly better than the control group and other possible samples. Practicing TCC may not necessarily improve QoL significantly greater than practicing other forms of exercise or even other hobbies and interests when good health is maintained. The correlations suggest that cognitive ability declines with age, and that higher years of experience in both interventions may not induce significant improvements in cognitive ability. The regressions indicate that the various activities and in particular, cognitive activities engaged in the lives of older people can predict working memory ability.

The results of the BPT and the Stroop Test correct responses have provided the most robust evidence that TCC could potentially improve working memory ability and executive function in the elderly and therefore combat cognitive decline. Ronnlund, Sundstrom and Nilsson (2015) found a close association between general cognitive ability and working memory, which demonstrates the importance of working memory regarding its relationship with cognition and the age at which cognitive health becomes a concern. Due to the low-intensity of the exercise of TCC and the biopsychosocial benefits discussed, it is an ideal health intervention to be publicly promoted to the elderly (Chen, Snyder & Krichbaum, 2001), however it may be preferable for people to take up the exercise before they undergo the process of cognitive decline from ageing to pre-emptively defend their neurological constitution. If physical interventions are employed earlier when treating Alzheimer's disease, they are more effective at controlling the negative symptoms (Phillips, 2015).

The findings of the present study must be interpreted with caution. The methodological limitations and mediating factors discussed (sampling problems and extraneous variables) make interpreting the implications of the study difficult. Such complications are common in this area of research where cognitive functions are not fully understood, and indeed TCC itself is a mysterious exercise. Hall, Miszko and Wolf (2009) mention 'frequent' use of visual imagery among TCC teachers, this is not always practiced in all forms of TCC. Since TCC can vary in forms, methods and styles of teaching, are many researchers fallaciously assuming that all TCC is the same? It is possible that different forms may illicit different cognitive enhancements, and the specifics of the form of TCC is sometimes not detailed in studies (Kelly et al., 2014).

Future research would benefit from more stringent sampling in order to account for the myriad of mediating factors. An equality of age, gender, degrees of practice (frequency, intensity, length of experience), education, health status are imperative to attain reliable and valid results. More research is required on the cognitive benefits of playing bowls in order for TCC to be compared to it comprehensively, and also for its capability in maintaining QoL for the elderly. Lastly, using multiple neuropsychological tests for the same area of cognition could provide data on which specific components of cognitive areas are improved by TCC. With attention to the main findings, a focus on working memory with the inclusion of various tests that measure other components of it such as visuospatial memory may be promising.

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Appendix 1

Brief Form

Experiment Brief

Dear Participant,

This experiment has been designed to test sustained attention, memory and executive function (a system of mental processing) using three short tests. These tests are completed on the computer, where instructions will be shown for each test and by the researcher. Feel free to ask the researcher any questions about what to do on the instructions screens before the tests begin. These tests require a lot of focus, so you will have 60 second breaks in between them. Including these breaks, the tests will last approximately 10 minutes. At the end we would like you also to complete a short questionnaire which is about how you describe quality of your life.

You may refuse to continue the experiment at any point as your participation is completely voluntary. Your name will not be used in the results in any way, your data will only correspond to a number. You also have the right to withdraw your results from the data after the experiment has been completed.

Thank you for taking part.

Statement of Consent:

I have read and understand the above information, and I consent to participate in this study.

Name: .... Date: ....

Signature: ....

Questionnaire

Personal Details Questionnaire

What is your gender?	Male / Female
What is your age?	....
Which of these activities do you practice regularly?	Tai chi / Bowls / Neither
How long have you been practicing this?	....
What other recreational activities do you practice?	....

Older People's Quality of Life Questionnaire - Brief (OPQOLQ-Brief)

Please answer the following statements truthfully by circling the most appropriate answer

I enjoy my life overall

Strongly disagree   Disagree   Neither agree nor disagree   Agree   Strongly agree

I look forward to things

Strongly disagree   Disagree   Neither agree nor disagree   Agree   Strongly agree

I am healthy enough to get out and about

Strongly disagree   Disagree   Neither agree nor disagree   Agree   Strongly agree

My family, friends or neighbours would help me if needed

Strongly disagree   Disagree   Neither agree nor disagree   Agree   Strongly agree

I have social or leisure activities/hobbies that I enjoy doing

Strongly disagree   Disagree   Neither agree nor disagree   Agree   Strongly agree

I try to stay involved with things

Strongly disagree Disagree Neither agree nor disagree Agree Strongly agree

I am healthy enough to have my independence

Strongly disagree Disagree Neither agree nor disagree Agree Strongly agree

I can please myself what I do

Strongly disagree Disagree Neither agree nor disagree Agree Strongly agree

I feel safe where I live

Strongly disagree Disagree Neither agree nor disagree Agree Strongly agree

I get pleasure from my home

Strongly disagree Disagree Neither agree nor disagree Agree Strongly agree

I take life as it comes and make the best of things

Strongly disagree Disagree Neither agree nor disagree Agree Strongly agree

I feel lucky compared to most people

Strongly disagree Disagree Neither agree nor disagree Agree Strongly agree

I have enough money to pay for household bills

Strongly disagree Disagree Neither agree nor disagree Agree Strongly agree

Debrief Form

Experiment Debrief

Thank you for completing the experiment. The purpose of the tests is to measure the attention, memory and executive function (a system of mental processing) of older people who practice tai chi, bowls or no physical exercise. The questionnaire is designed to measure quality of life. These participated groups will then be compared to determine whether tai chi can significantly improve the brain power and quality of life of older people.

You have the right to withdraw your scores from the data. You may also request your results or group results at any time once the experiment has been completed. If you wish to do either of these, or have any further questions, please contact the student email provided.

Thank you very much again for giving your time.

Student Email: james.willmott@study.beds.ac.uk

Supervisor Email: candan.ertubey@beds.ac.uk

Below please see list of public services which you may be interested in getting in touch with after your engagement in this research project.

Public Service Information Groups:

Tai Chi : http://www.worldtaichiday.org/

Aging : http://www.ageuk.org.uk/

Alzheimer's & Dementia : http://www.alzheimersresearchuk.org/

Example Sheet for Instructions

This sheet was printed and shown to the participants to aid with the explanation of the instructions.

Stroop Test Example

Red Blue Green

Red Blue Green

Brown-Peterson Task Example

YHF

Please count backwards in threes from 339

Please recall the trigram out loud to the researcher

List of Additional Activities

Listed here are all of the self-reported additional activities that were recorded. The purpose of this list is to disclose how all of these activities were categorised.

Aerobic Activities:

Swimming, cycling, dancing, keep fit, exercises to music, yoga, ballet, pilates, aqua-aerobics, mountaineering, gym

Non-aerobic Activities:

Gardening, skittles, table-tennis

Walking

Mental Exercises:

Reading, T.V, needlework, history, university of the third age, upholstery, knitting, bridge, crosswords, quilting, photography, crochet, painting

Instrument/Music:

Bass, piano, guitar, singing, choir, violin

Appendix 2

Table 6

Descriptive Statistics for Age by Gender and Group

Group	Gender	Mean	Std. Deviation	N
Tai Chi Chuan	Male	71.60	7.02	5
	Female	74.36	6.47	25
	Total	73.90	6.53	30
Bowls	Male	74.20	5.21	20
	Female	69.90	3.93	10
	Total	72.77	5.18	30
Control	Male	77.00	10.54	3
	Female	76.29	6.95	7
	Total	76.50	7.55	10
Total	Male	74.04	6.06	28
	Female	73.62	6.32	42
	Total	73.79	6.17	70

Table 7

Descriptive Statistics for Test Order

Dependent Variable	Test Order	Mean	Std. Deviation	N
SART Mean RT	BPT SART Stroop	257.825	24.816	28
	SART Stroop BPT	259.018	14.306	20
	Stroop BPT SART	246.339	45.660	19
	Total	254.924	30.155	67
SART Std. Dev RT	BPT SART Stroop	37.691	20.915	27
	SART Stroop BPT	36.126	17.696	20
	Stroop BPT SART	43.033	18.683	19
	Total	38.754	19.264	66
SART Correct Responses	BPT SART Stroop	63.300	27.934	30
	SART Stroop BPT	81.550	42.439	20
	Stroop BPT SART	78.400	43.774	20
	Total	72.829	37.710	70
SART Omission Errors	BPT SART Stroop	137.667	31.502	30
	SART Stroop BPT	118.000	47.272	20
	Stroop BPT SART	121.600	49.196	20
	Total	127.457	42.191	70
SART Commission Errors	BPT SART Stroop	6.033	4.529	30
	SART Stroop BPT	7.450	5.226	20
	Stroop BPT SART	7.000	5.921	20
	Total	6.714	5.116	70
SART Total Errors	BPT SART Stroop	143.700	27.934	30
	SART Stroop BPT	125.450	42.439	20
	Stroop BPT SART	128.600	43.774	20
	Total	134.171	37.710	70
Stroop Mean RT	BPT SART Stroop	1234.137	295.187	30
	SART Stroop BPT	1098.935	299.894	20
	Stroop BPT SART	1441.696	388.185	20
	Total	1254.811	346.746	70
Stroop Std. Dev RT	BPT SART Stroop	517.542	292.436	30
	SART Stroop BPT	492.076	365.673	20
	Stroop BPT SART	831.367	521.747	20
	Total	599.930	411.790	70
Stroop Correct Responses	BPT SART Stroop	55.100	7.416	30
	SART Stroop BPT	57.300	3.164	20
	Stroop BPT SART	57.850	2.834	20
	Total	56.514	5.445	70
BPT Correct Responses	BPT SART Stroop	2.233	1.612	30
	SART Stroop BPT	2.350	1.496	20
	Stroop BPT SART	2.450	1.146	20
	Total	2.329	1.442	70

Table 8

Test Order ANOVA

Dependent Variable	df	F	*p*	Partial η^2
SART Mean RT	2	1.087	.343	.033
SART Std. Dev. RT	2	.689	.506	.021
SART Correct Responses	2	1.748	.182	.050
SART Omission Errors	2	1.601	.209	.046
SART Commission Errors	2	.496	.611	.015
SART Total Errors	2	1.748	.182	.050
Stroop Mean RT	2	5.650**	.005	.144
Stroop Std. Dev. RT	2	4.955**	.010	.129
Stroop Correct Responses	2	1.868	.162	.053
BPT Correct Responses	2	.135	.874	.004

Note. * indicates significance at the level of $p<0.05$. ** indicates significance at the level of $p<0.01$. *** indicates significance at the level of $p<0.001$.

Table 9

Chi Square for Aerobic Exercise

			Aerobic		Total
			No	Yes	
Group	TCC	Count	13	17	30
		Expected Count	19.7	10.3	30
		% within Group	43.3%	56.7%	100%
		% within Aerobic	28.3%	70.8%	42.9%
		% of Total	18.6%	24.3%	42.9%
	Bowls	Count	26	4	30
		Expected Count	19.7	10.3	30
		% within Group	86.7%	13.3%	100%
		% within Aerobic	56.5%	16.7%	42.9%
		% of Total	37.1%	5.7%	42.9%
	Control	Count	7	3	10
		Expected Count	6.6	3.4	10
		% within Group	70%	30%	100%
		% within Aerobic	15.2%	12.5%	14.3%
		% of Total	10%	4.3%	14.3%
Total		Count	46	24	70
		Expected Count	46	24	70
		% within Group	65.7%	34.3	100%
		% within Aerobic	100%	100%	100%
		% of Total	65.7%	34.3%	100%

Table 10

Chi Square for Non-Aerobic Exercise

			Non-Aerobic		
			No	Yes	Total
Group	TCC	Count	28	2	30
		Expected Count	24	6	30
		% within Group	93.3%	6.7%	100%
		% within Non-Aerobic	50%	14.3%	42.9%
		% of Total	40%	2.9%	42.9%
	Bowls	Count	21	9	30
		Expected Count	24	6	30
		% within Group	70%	30%	100%
		% within Non-Aerobic	37.5%	64.3%	42.9%
		% of Total	30%	12.9%	42.9%
	Control	Count	7	3	10
		Expected Count	8	2	10
		% within Group	70%	30%	100%
		% within Non-Aerobic	12.5%	21.4%	14.3%
		% of Total	10%	4.3%	14.3%
Total		Count	56	14	70
		Expected Count	56	14	70
		% within Group	80%	20%	100%
		% within Non-Aerobic	100%	100%	100%
		% of Total	80%	20%	100%

Table 11

Chi Square for Walking

			Walking		Total
			No	Yes	
Group	TCC	Count	15	15	30
		Expected Count	15	15	30
		% within Group	50%	50%	100%
		% within Walking	42.9%	42.9%	42.9%
		% of Total	21.4%	21.4%	42.9%
	Bowls	Count	16	14	30
		Expected Count	15	15	30
		% within Group	53.3%	46.7%	100%
		% within Walking	45.7%	40%	42.9%
		% of Total	22.9%	20%	42.9%
	Control	Count	4	6	10
		Expected Count	5	5	10
		% within Group	40%	60%	100%
		% within Walking	11.4%	17.1%	14.3%
		% of Total	5.7%	8.6%	14.3%
Total		Count	35	35	70
		Expected Count	35	35	70
		% within Group	50%	50%	100%
		% within Walking	100%	100%	100%
		% of Total	50%	50%	100%

Table 12

Chi Square for Mental Activities

			Mental		Total
			No	Yes	
Group	TCC	Count	20	10	30
		Expected Count	22.3	7.7	30
		% within Group	66.7%	33.3%	100%
		% within Mental	38.5%	55.6%	42.9%
		% of Total	28.6%	14.3%	42.9%
	Bowls	Count	27	3	30
		Expected Count	22.3	7.7	30
		% within Group	90%	10%	100%
		% within Mental	51.9%	16.7%	42.9%
		% of Total	38.6%	4.3%	42.9%
	Control	Count	5	5	10
		Expected Count	7.4	2.6	10
		% within Group	50%	50%	100%
		% within Mental	9.6%	27.8%	14.3%
		% of Total	7.1%	7.1%	14.3%
Total		Count	52	18	70
		Expected Count	52	18	70
		% within Group	74.3%	25.7%	100%
		% within Mental	100%	100%	100%
		% of Total	74.3%	25.7%	100%

Table 13

Chi Square for Music Activities

			Music		Total
			No	Yes	
Group	TCC	Count	26	4	30
		Expected Count	25.3	4.7	30
		% within Group	86.7%	13.3%	100%
		% within Music	44.1%	36.4%	42.9%
		% of Total	37.1%	5.7%	42.9%
	Bowls	Count	30	0	30
		Expected Count	25.3	4.7	30
		% within Group	100%	0%	100%
		% within Music	50.8%	0%	42.9%
		% of Total	42.9%	0%	42.9%
	Control	Count	3	7	10
		Expected Count	8.4	1.6	10
		% within Group	30%	70%	100%
		% within Music	5.1%	63.6%	14.3%
		% of Total	4.3%	10%	14.3%
Total		Count	59	11	70
		Expected Count	59	11	70
		% within Group	84.3%	15.7%	70
		% within Music	100%	100%	100%
		% of Total	84.3%	15.7%	100%